Chatbot: Semantic Parsing and Logical Forms

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Outline

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An Example Chatbot

Example

Table: Lunch Ordering

	Utterance	Intent
M	Hello, can I help you?	greeting
H	Yes, I'd like to have some luch	askMenu
M	Would you like a starter?	askStarter
H	Yes, I'd like a chicken soup, please	chooseStarter
M	Would you like anything to drink?	askDrink
H	No, thanks	confirmation

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Every chatbot needs **intent detection** and **entity extraction**.

Is Your Bot Intelligent?

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Is Your Bot Intelligent?

- Intent detection and entity extraction are not sufficient to make your chatbots intelligent
- They cannot answer questions such as:
  - *What is the tallest mountain in Vietnam?*
  - *What is the capital in Vietnam?*
  - *What is three plus three plus one?*
  - *Who is Obama?*

Outline

Two Main Components of a Chatbot System

1. **AI Engine**: language understanding & intent detection
2. **Dialog Engine**: state machine that executes context-driven workflows with scope variables

Semantic Parsing

A semantic parsing maps natural language utterances into an intermediate logical form, which is executed to produce a denotation.

A simple arithmetic task

- Utterance: "What is three plus four?"
- Logical form: $(+\ 3\ 4)$
- Denotation: 7

A question answering task

- Utterance: "What is the capital of Vietnam?"
- Logical form: (capital "Vietnam")
- Denotation: "Hanoi"

Semantic Parsing

A travel agent bot

- Utterance: *Show me flights to Hanoi leaving tomorrow*
- Logical form: *(and (type flight) (destination Hanoi) (departureDate 2018.05.10))*
- Denotation: *(list ...)*

Semantic Representations

- Semantic representations are generally logical forms, which are expressions in a fully specified, unambiguous artificial language.
- There are a variety of different formalisms:
  - lambda calculus
  - natural logics
  - diagrammatic languages
  - programming languages
  - robot controller languages
  - Grammar formalism based schemes:
    - Dependency Formalism
    - Combinatory Categorial Grammar (CCG)
    - Head-Phrase Structure Grammar (HPSG)
    - Lexicalized Tree Adjoining Grammar (LTAG)
  - database query languages
  - knowledge-based query languages (SPARQL, etc.)
  - lambda dependency-based compositional semantics

Logical Forms

Logical Forms

A **logical form** is a hierarchical expression. Primitive logical forms represent concrete values:

- (boolean true)
- (number 23)
- (string "Chao buoi sang")
- (fb:en.obama)

Logical Forms

- Logical forms can be constructed recursively by a function name followed by arguments, which are themselves logical forms
  - `(call + (number 3) (number 4))`
  - `(call java.lang.Math.cos (number 0))`
  - `(call if (call < (number 3) (number 4)) (string yes) (string no))`
  - `(call .indexOf (string "Duyet dep trai") (string "dep"))`
- We can execute a logical form and get the denotation (answer):

```
(call + (number 3) (number 4))
              ⇓
          (number 7)
```

Parsing Utterances to Logical Forms

- **How to map a natural language utterance into a logical form?**
- The key framework is compositionality:
  - The meaning of a full sentence is created by combining the meanings of its parts
  - Meanings are represented by logical forms.
- Classical and powerful approach: use a **formal grammar**.

Formal grammar

A grammar is a set of rules which specify how to combine logical forms to build more complex ones in a manner that is guided by the natural language

Example

- `(rule $Expr ($PHRASE) (NumberFn))`
- `(rule $Operator (plus) (ConstantFn (lambda y (lambda x (call +(var x)(var y))))))`
- `(rule $Operator (times) (ConstantFn (lambda y (lambda x (call * (var x)(var y))))))`
- `(rule $Partial (`*Operator*`Expr) (JoinFn forward))`

Parsing

- Now, the utterance "What is three plus four?" should give the output (number 7)
- A longer sentence such as "What is three plus four times two? should give two derivations:
  - `(number 14)`
  - `(number 11)`
- A parser is an actual algorithm that takes the grammar and generates those derivations.
  - INP: `What is three plus four?`
  - OUT: `(derivation (formula (((lambda y (lambda x (call + (var x) (var y)))) (number 4)) (number 3))) (value (number 7)))`

Parsing Utterances to Logical Forms

- A given utterance might be consistent with multiple logical forms, creating ambiguity
- `INP: What is three plus four times two?`
- OUT:
  1. `(derivation (formula (((lambda y (lambda x (call + (var x) (var y)))) (((lambda y (lambda x (call * (var x) (var y)))) (number 2)) (number 4))) (number 3))) (value (number 11)))`
  2. `(derivation (formula (((lambda y (lambda x (call * (var x) (var y)))) (number 2)) (((lambda y (lambda x (call + (var x) (var y)))) (number 4)) (number 3)))) (value (number 14)))`

Parsing Utterances to Logical Forms

- Computational challenge: the number of candidate logical forms is in general exponential in the length of the sentence.
- In the question *What kind of system of government does the United States have?* (Berant et al., 2013):
  - the phrase "United States" maps to 231 entities in the lexicon,
  - the verb "have" maps to 203 binaries,
  - the phrases "kind", "system", and "government" all map to many different unary and binary predicates.

Learning

- Machine learning concerns the ability to generalize from a set of past observations or experiences in a way that leads to improved performance on a future task (T. Mitchel, 1997).
- A ML system has 3 integral pieces:
    1. a **feature representation** of the data
    2. an **objective function**
    3. an algorithm for **optimizing** the objective function

Using Machine Learning to get Logical Forms

Using Machine Learning for Parsing Utterances to Logical Forms?

Summary

- Many existing chatbot systems have mostly used a swallow semantic representation of text, disregarding significant meaning encoded in human language
- Recent logical and statistical approaches have identified methods for mapping utterances to meanings efficiently.

For Further Reading I

- Jonathan Herzig and Jonathan Berant, "Neural Semantic Parsing over Multiple Knowledge-bases", Proceedings of ACL, 2017
- Jonathan Berant et al., "Semantic Parsing on Freebase from Question-Answer Pairs", Proceedings of EMNLP, 2013.
- Phuong Le-Hong and Duc-Thien Bui, "A Factoid Question Answering System for Vietnamese", Proceedings of WWW Companion, 2018.